ANALOG DEVICES

AN-17
APPLICATION NOTE

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DAC-08
Applications Collection

GENERAL DESCRIPTION

There has been a trend in recent years toward providing totally dedicated digital-to-analog converters with limited applications versatility. This application note describes a new type of monolithic DAC designed for an extremely broad range of applications, the Analog Devices DAC-08.

Several unique design features of this low-cost DAC combine to provide total applications flexibility. Principal among them are: dual complementary, true current outputs; universal logic inputs capable of interfacing with any logic family; 85ns settling time; high-speed multiplying capability; and finally, the ability to use any standard system power supply voltages. A description of these features is given followed by specific applications using each feature.

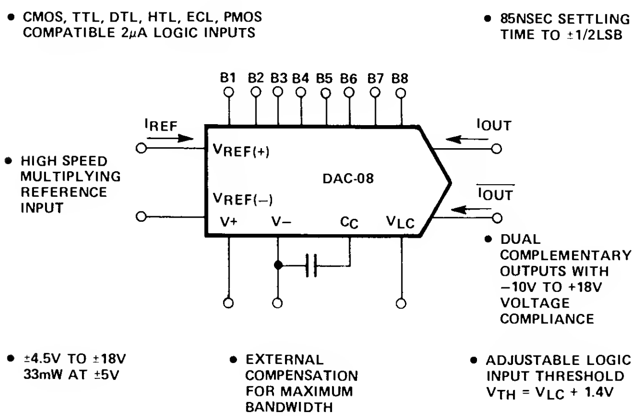


Figure 1. The Flexible D/A Converter

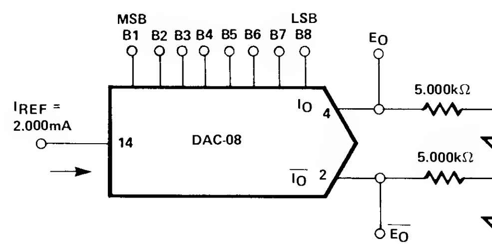
OUTPUT

HIGH VOLTAGE COMPLIANCE CURRENT OUTPUTS

Many older current-output DACs actually have resistive outputs which must be terminated in a virtual ground. The DAC-08, however, is a true digitally-controlled current source with an output impedance typically exceeding 20MΩ.

Its outputs can swing between −10V and +18V with little or no effect on full-scale current or linearity. Some of the applications that require high output voltage compliance include:

1. Precise current transmission over long distances.
2. Programmable current sources.
3. Analog meter movement driving.
4. Resistive termination for a voltage output without an op amp.
5. Capacitive termination for digitally-controlled integrators.
6. Inductive termination with balanced transformers, transducers and headsets.



	B1	B2	B3	B4	B5	B6	B7	B8	I_O mA	$\overline{I_O}$ mA	E_O	$\overline{E_O}$
FULL SCALE −1LSB	1	1	1	1	1	1	1	1	1.992	0.000	−9.960	0.000
FULL SCALE −2LSB	1	1	1	1	1	1	1	0	1.984	0.008	−9.920	− 0.40
HALF SCALE +LSB	1	0	0	0	0	0	0	1	1.008	0.984	−5.040	−4.920
HALF SCALE	1	0	0	0	0	0	0	0	1.000	0.992	−5.000	−4.960
HALF SCALE −LSB	0	1	1	1	1	1	1	1	0.992	1.000	−4.960	−5.000
ZERO SCALE +LSB	0	0	0	0	0	0	0	1	0.008	1.984	−0.040	−9.920
ZERO SCALE	0	0	0	0	0	0	0	0	0.000	1.992	0.000	−9.960

Figure 2. Basic Unipolar Negative Operation

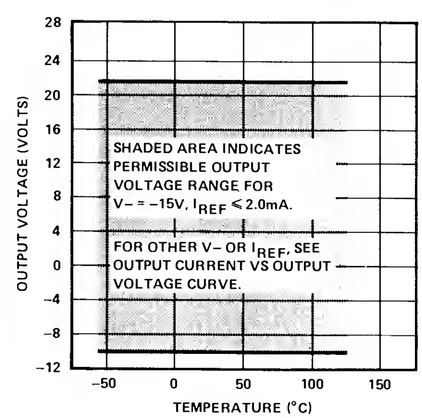


Figure 3. Output Voltage Compliance vs Temperature

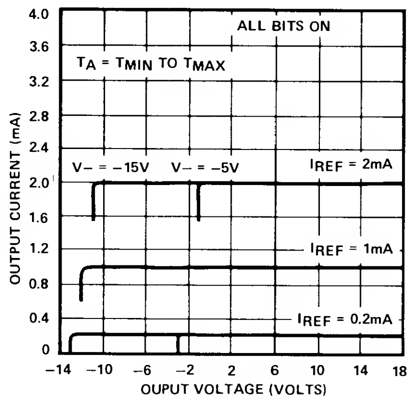
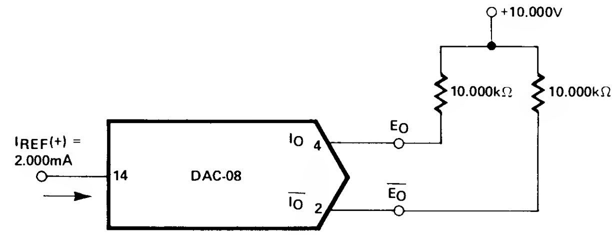
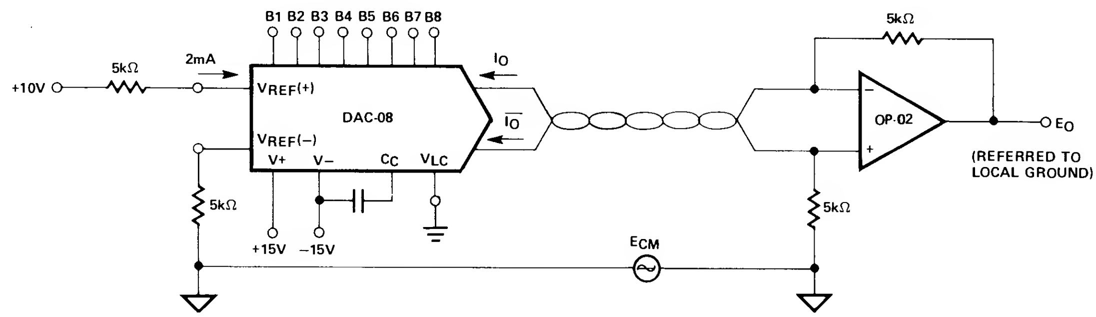


Figure 4. Output Current vs Output Voltage (Output Voltage Compliance)



	B1 B2 B3 B4 B5 B6 B7 B8	E_O	$\overline{E_O}$
POS FULL SCALE –LSB	1 1 1 1 1 1 1 1	– 9.920	+10.000
POS FULL SCALE 2LSB	1 1 1 1 1 1 1 0	– 9.840	+ 9.920
ZERO SCALE +LSB	1 0 0 0 0 0 0 1	– 0.080	+ 0.160
ZERO SCALE	1 0 0 0 0 0 0 0	0.000	+ 0.080
ZERO SCALE –LSB	0 1 1 1 1 1 1 1	+ 0.080	0.000
NEG FULL SCALE +LSB	0 0 0 0 0 0 0 1	+ 9.920	– 9.840
NEG FULL SCALE	0 0 0 0 0 0 0 0	+10.000	– 9.920

Figure 5. Basic Bipolar Output Operation



	B1 B2 B3 B4 B5 B6 B7 B8	E_O
POS FULL SCALE –LSB	1 1 1 1 1 1 1 1	+9.920
POS FULL SCALE 2LSB	1 1 1 1 1 1 1 0	+9.840
(+) ZERO SCALE	1 0 0 0 0 0 0 0	+0.040
(–) ZERO SCALE	0 1 1 1 1 1 1 1	–0.040
NEG FULL SCALE +2LSB	0 0 0 0 0 0 0 1	–9.840
NEG FULL SCALE +1LSB	0 0 0 0 0 0 0 0	–9.920

Figure 6. High Noise Immunity Current to Voltage Conversion

DUAL COMPLEMENTARY OUTPUTS

Convertional DACs have a single output, so they cannot drive balanced loads and are limited to a single input code polarity. The DAC-08 was designed to overcome these limitations.

Input coding of positive binary or complementary binary is obtained by a choice of outputs, I_O for positive-true or I_O for negative-true. In many applications both are used either independently or in combination. Dual comlementary outputs allow some very unusual and useful DAC applications:

1. CRT display driving without transformers.
2. Differential transducer control systems.
3. Differential line driving.
4. High-speed waveform generation.
5. Digitally controlled offset nulling of op amps.

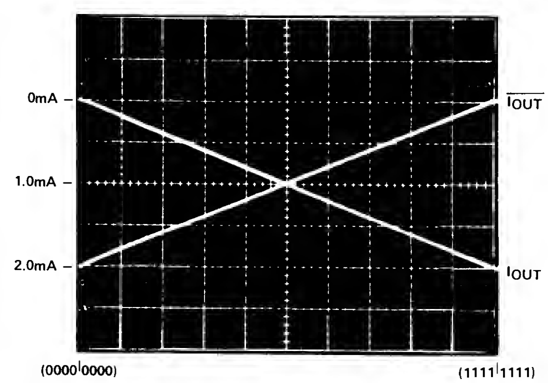


Figure 7. True and Complementary Output Operation

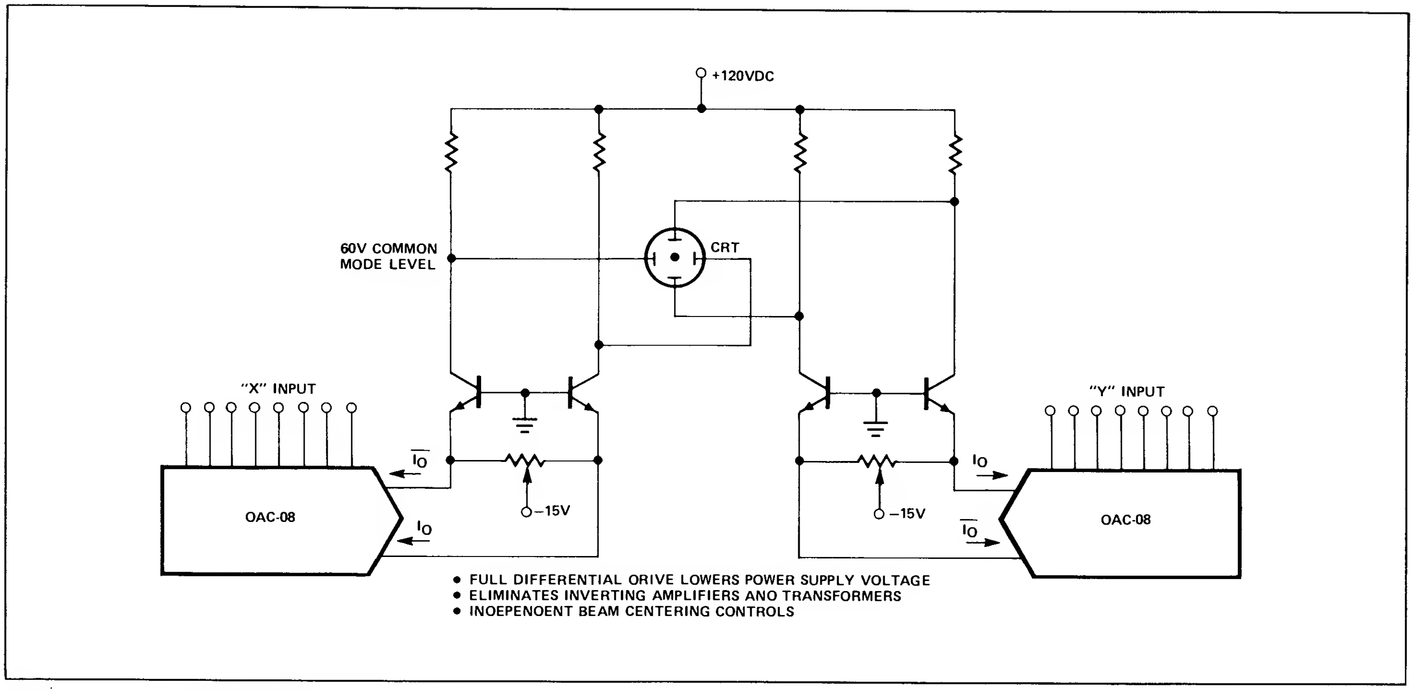


Figure 8. CRT Display Driver

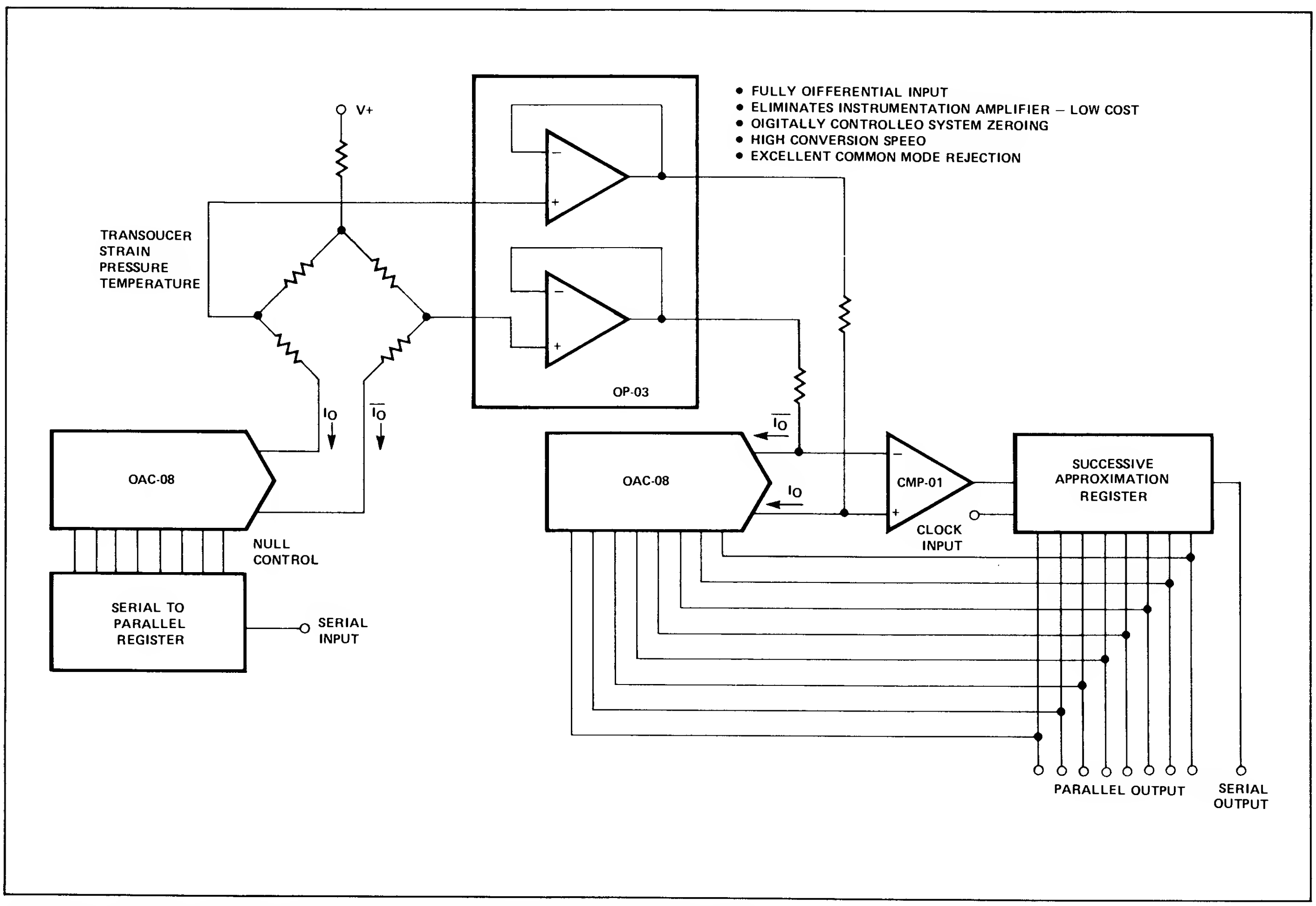
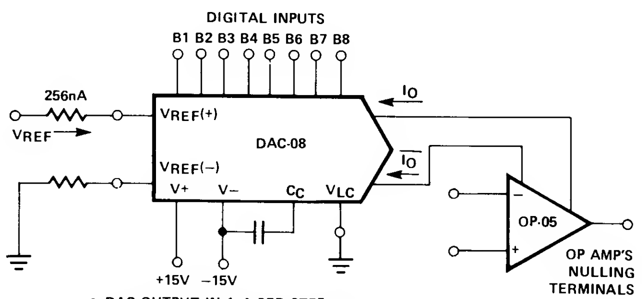
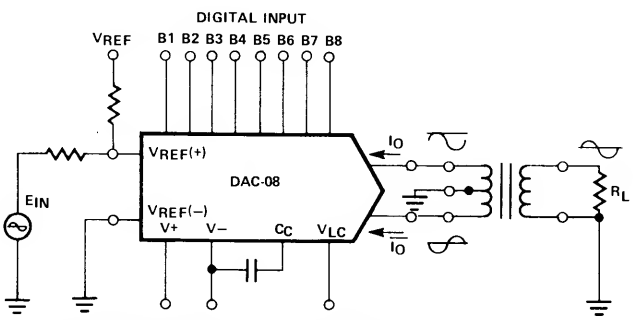


Figure 9. Bridge Transducer Control System with Full Differential Input



- DAC OUTPUT IN 1nA PER STEP
- REPLACES NULLING POTENTIOMETER
- WORKS WITH OP-07, OP-05, SSS725
- V_{OS} NULLED BELOW NOISE LEVEL

Figure 10. Digitally Controlled Offset Nulling



- BIPOLAR OUTPUT WITH OFFSET BINARY CODING
- PROVIDES DC ISOLATION BETWEEN SOURCE AND LOAD
- HIGH VOLTAGE OUTPUT CAPABILITY
- USEFUL WITH PULSE OR SINE WAVE REFERENCE INPUT
- USEFUL WITH PULSE OR SINE FUNCTION DIGITAL INPUT

Figure 11. Balanced Transformer Drive

HIGH SPEED

Sub-microsecond settling times are common in current-output DACs. Many DACs settle in 500ns; 300ns is not unusual. But 85ns settling time for a low-cost DAC is exceptional, and this characteristic allows the use of the DAC-08 in formerly difficult and expensive-to-build applications:

1. 1μs, 2μs and 4μs A/Ds. (These are completely described in AN-16.)
2. 15MHz Tracking A/Ds.
3. ECL compatible applications.
4. Video displays requiring a low-glitch DAC.
5. Radar pulse height analysis system.

LOGIC INPUTS

ADJUSTABLE INPUT LOGIC THRESHOLD

Most DACs have TTL or CMOS compatible inputs which require complicated interfaces for use with ECL, PMOS, NMOS or HTL logic. By contrast, the DAC-08, with typical logic input current of 2μA and an adjustable input logic threshold, interfaces easily with any logic family in use today. The logic input threshold is 1.4V positive with respect to Pin 1; for TTL Pin 1 is therefore grounded; for other families Pin 1 is connected as shown in the interfacing figure. An adjustable threshold and a −10V to +18V input range greatly simplify system design especially with other-than-TTL logic. The circuits shown in c and d provide a $2V_{BE}$ V_{LC} compensation to minimize temperature drift.

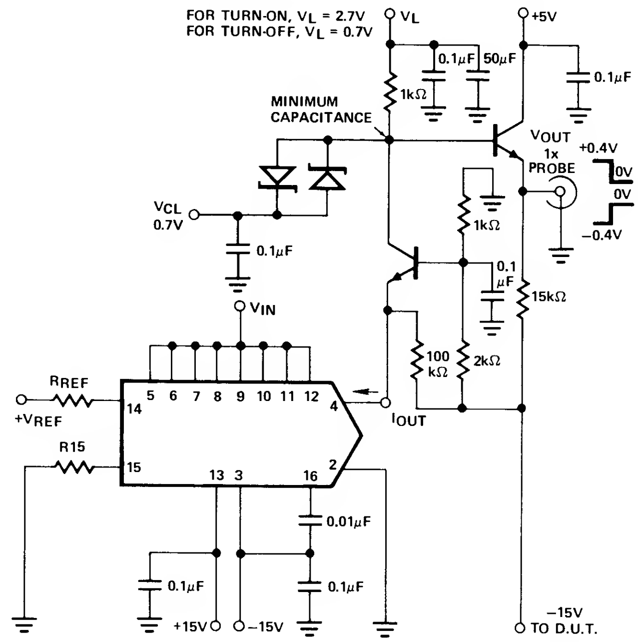


Figure 12. Settling Time Measurement Circuit

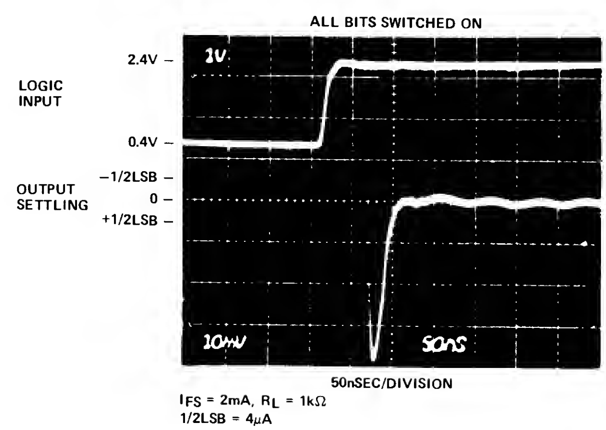


Figure 13. Full Scale Settling Time

1. ECL applications without level translators.
2. Direct interfaces with Hi-Z RAM outputs.
3. CMOS applications without static discharge considerations.
4. HTL or HNIL applications without level translators.
5. System size, weight, and cost reduction.

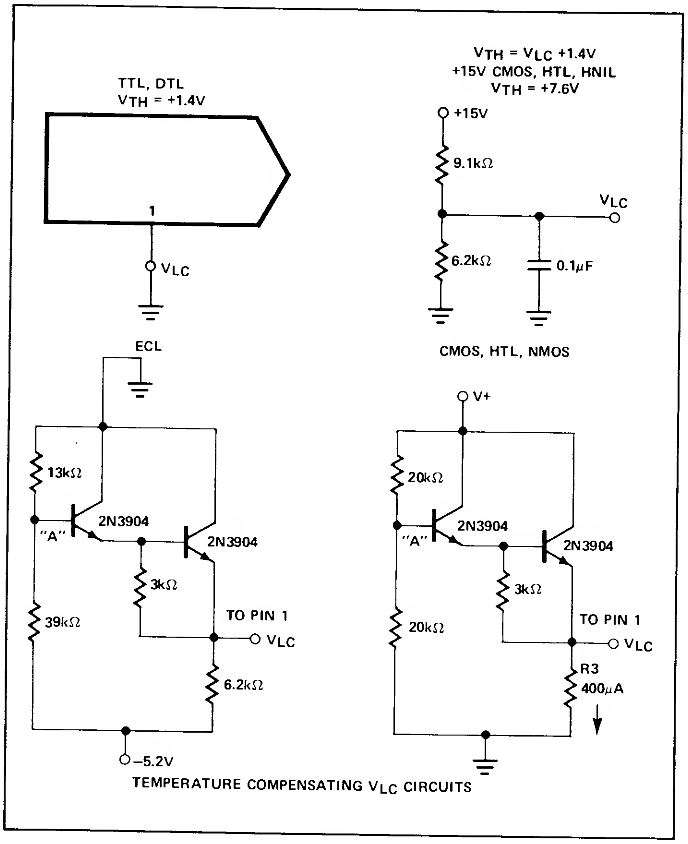


Figure 14. Interfacing with Various Logic Families ($V_{TH} = V_{LC} + 1.4V$)

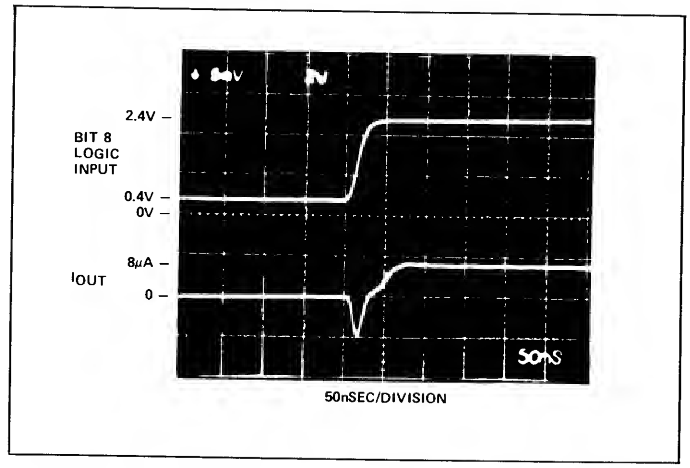


Figure 16. LSB Switching

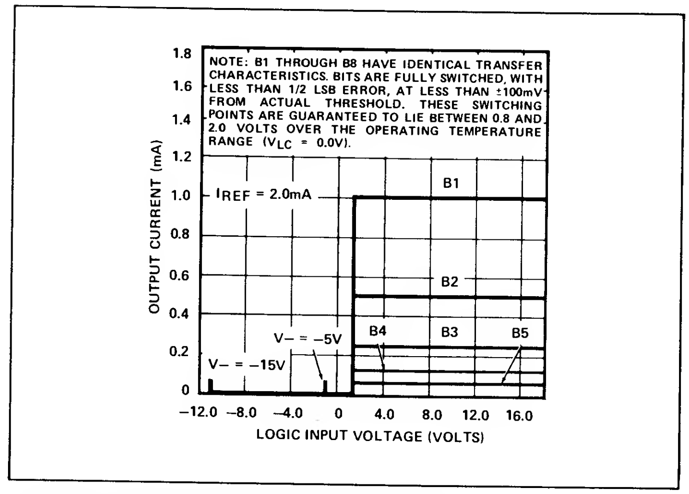


Figure 17. Bit Transfer Characteristics

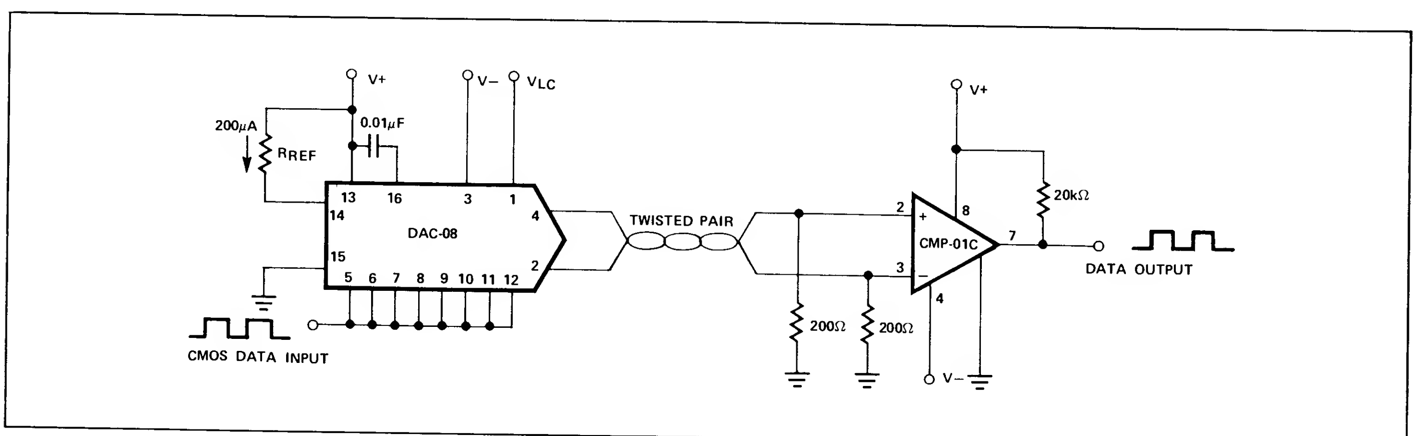


Figure 15. CMOS Differential Line Driver/Receiver

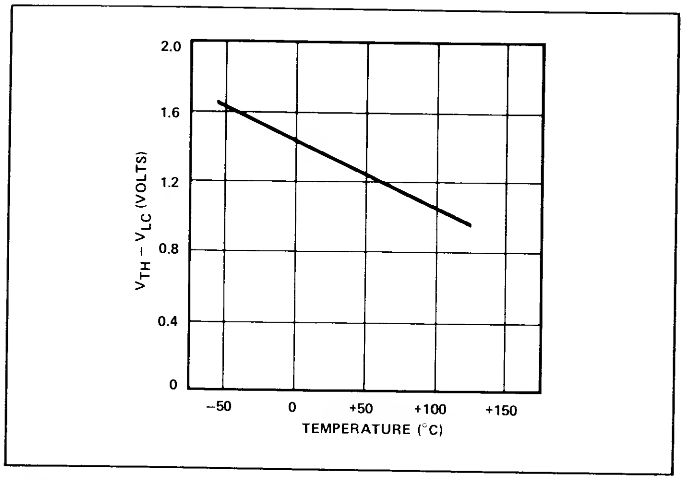


Figure 18. $V_{TH} - V_{LC}$ vs Temperature

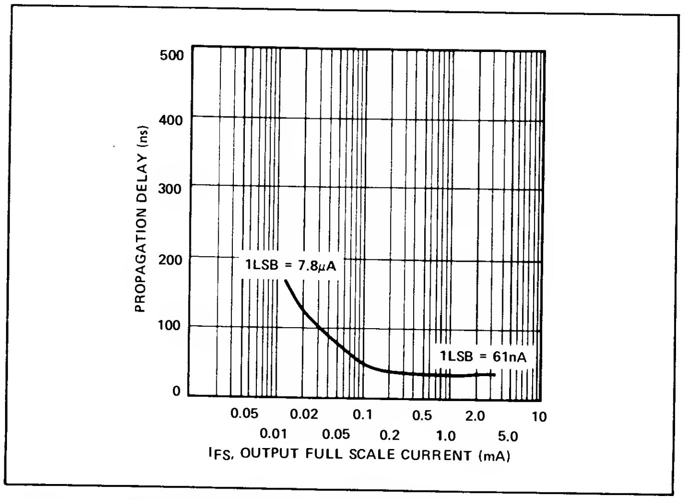


Figure 19. LSB Propogation Delay vs I_{FS}

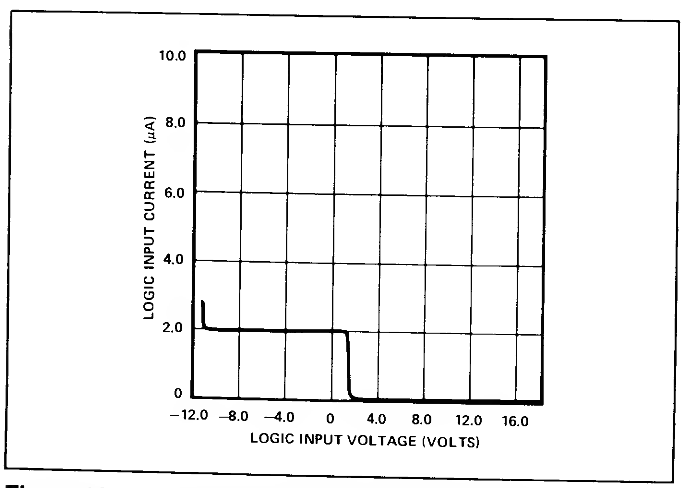


Figure 20. Logic Input Current vs Input Voltage

REFERENCE INPUTS

MULTIPLYING CAPABILITY

Fixed internal references are included in many DACs, but they limit the user to non-multiplying, single-polarity reference applications and do not allow a single-system reference. To achieve the design goals of low cost and total applications flexibility, the DAC-08 uses an external reference. Positive or negative references may be applied over a wide common-mode voltage range. In addition, the full-scale current is matched to the reference current eliminating calibration in most applications.

1. Digitally controlled full-scale calibration.
2. 8 x 8 multiplication of two digital words.
3. Digital Attenuators/Programmable gain amplifiers.
4. Modem transmitters to 1MHz.
5. Remote shutdown and party line DAC applications.

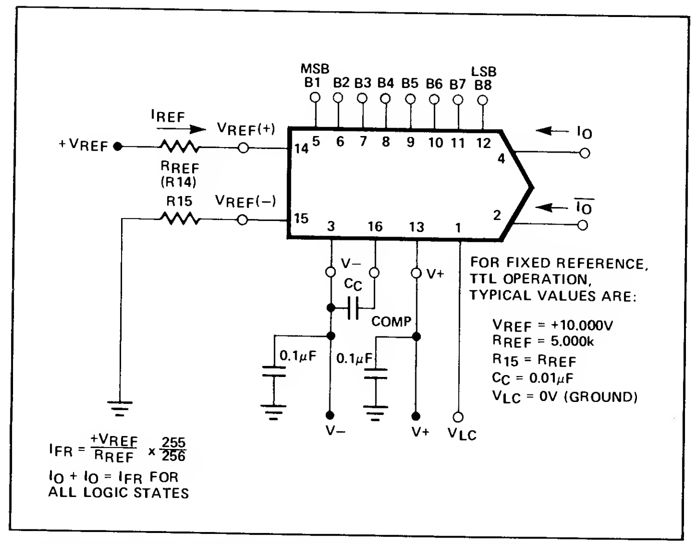


Figure 21. Basic Positive Reference Operation

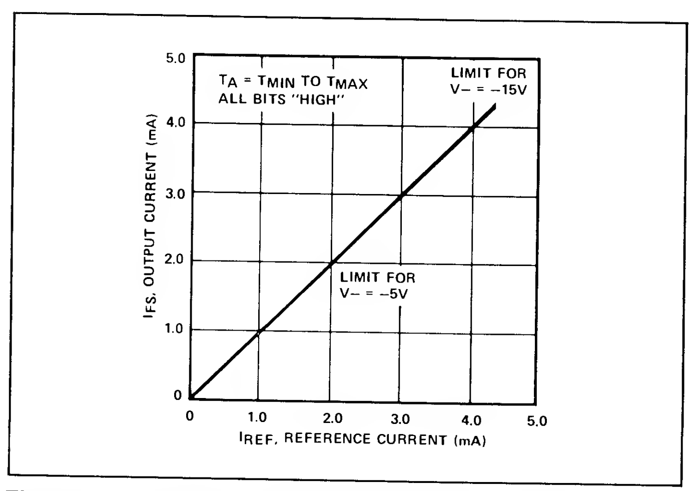


Figure 22. Full-Scale Current vs Reference Current

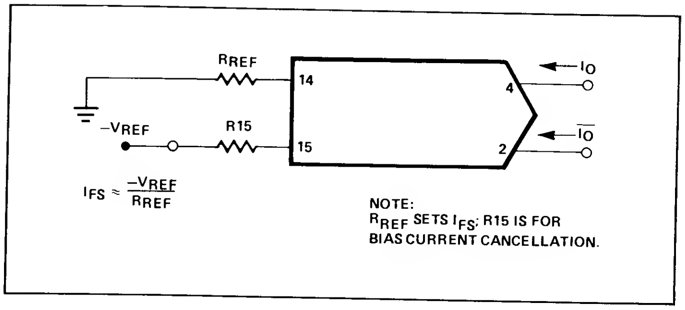


Figure 23. Basic Negative Reference Operation

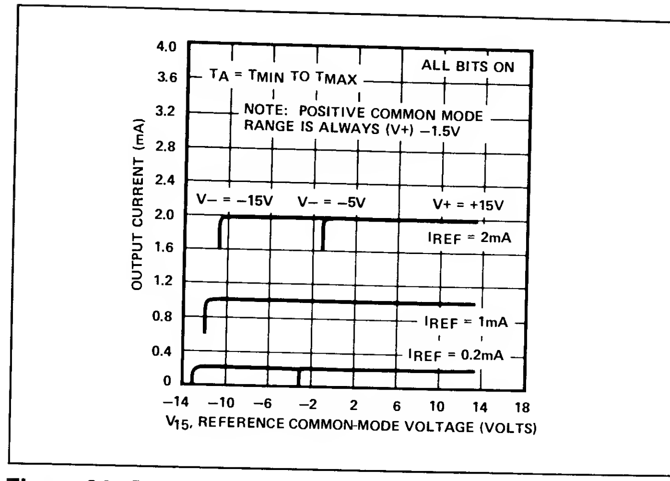


Figure 24. Reference Amp Common-Mode Range

HIGH SPEED

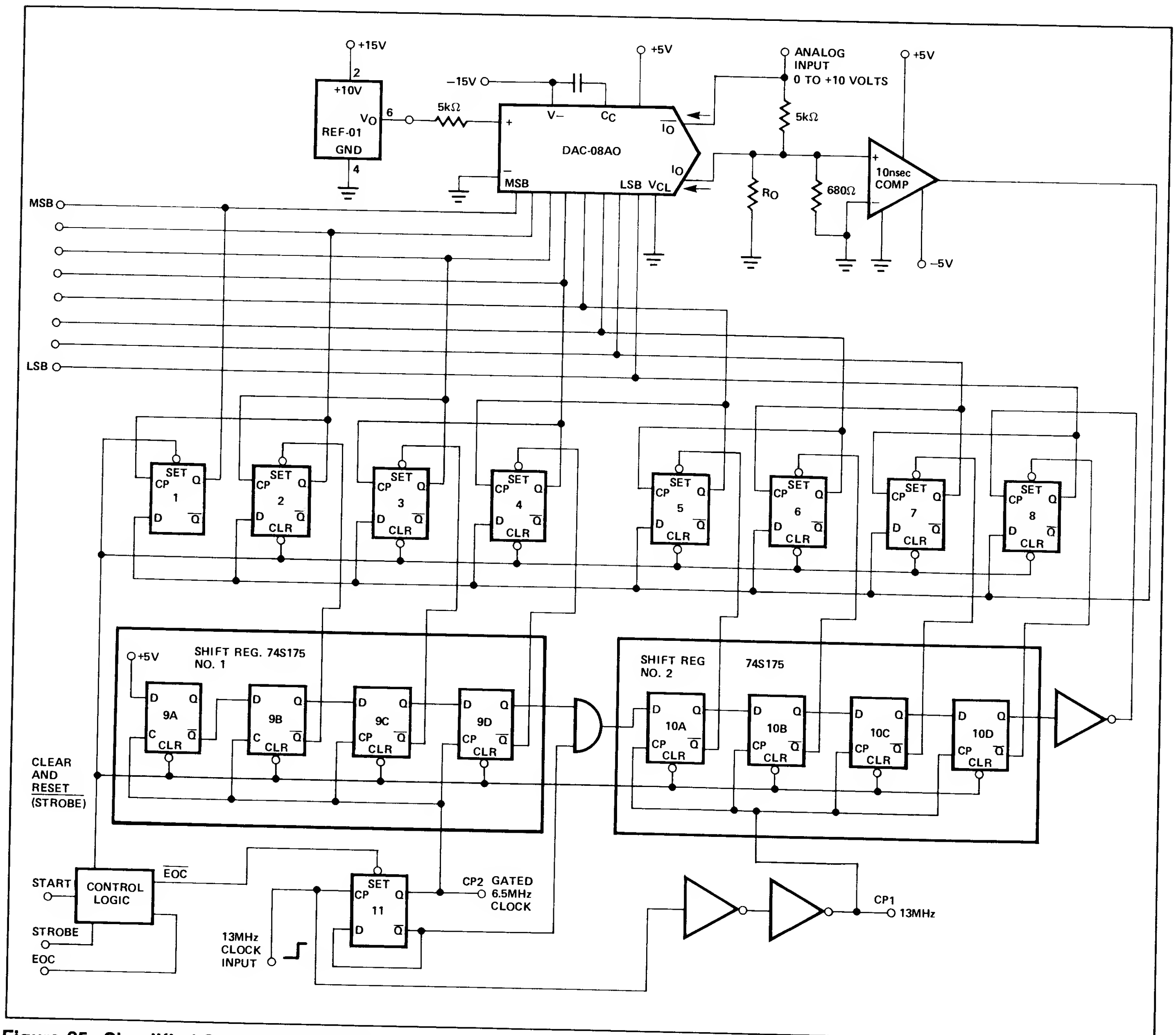


Figure 25. Simplified Schematic 1μs A/D

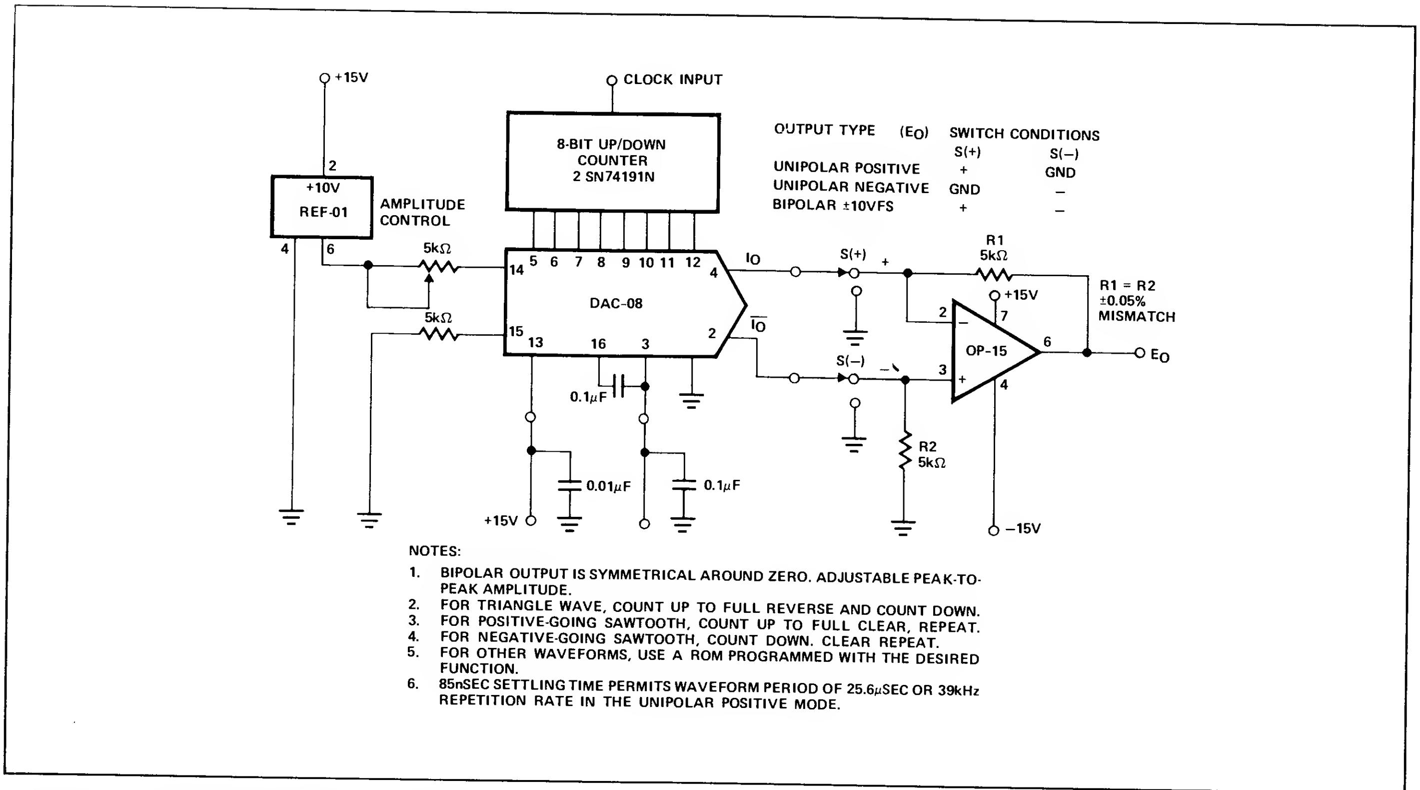


Figure 26. High-Speed Waveform Generator

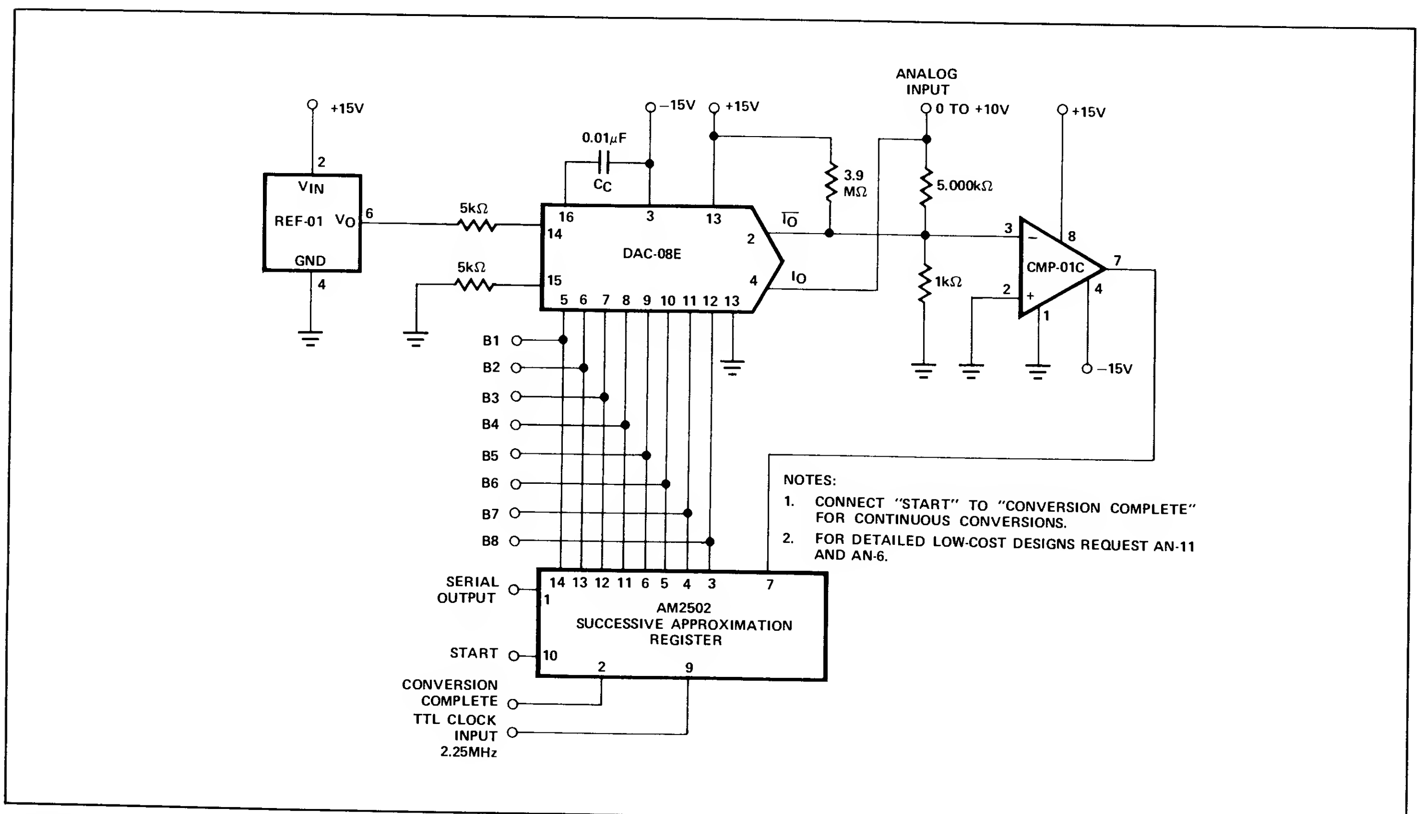


Figure 27. Four IC Low-Cost A/D Converter

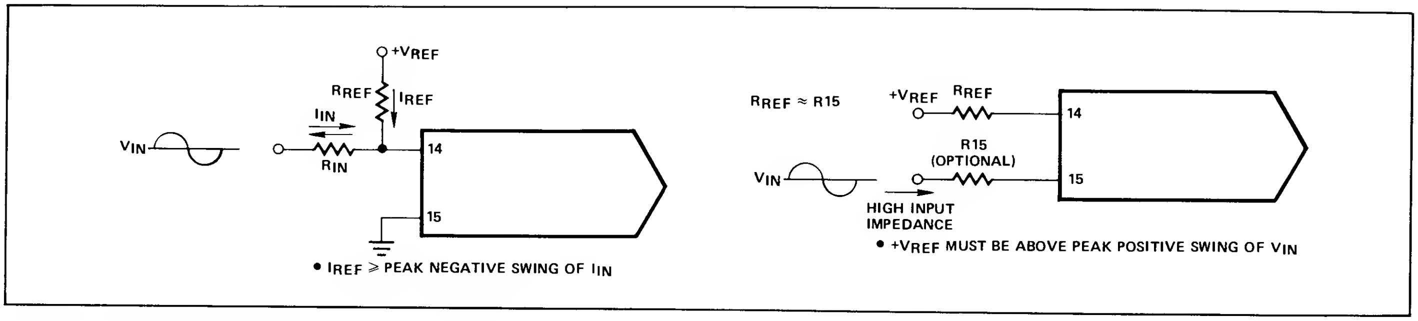


Figure 28. Accommodating Bipolar References

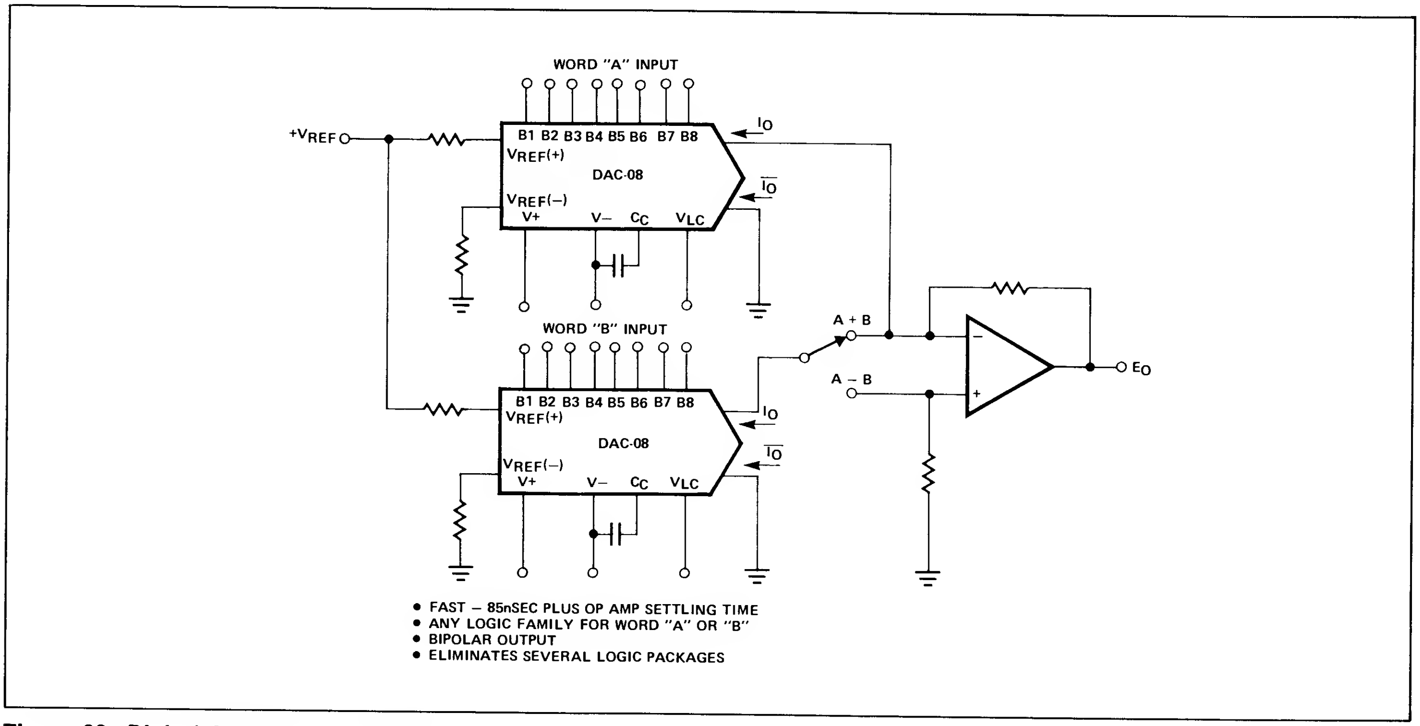


Figure 29. Digital Addition or Subtraction with Analog Output

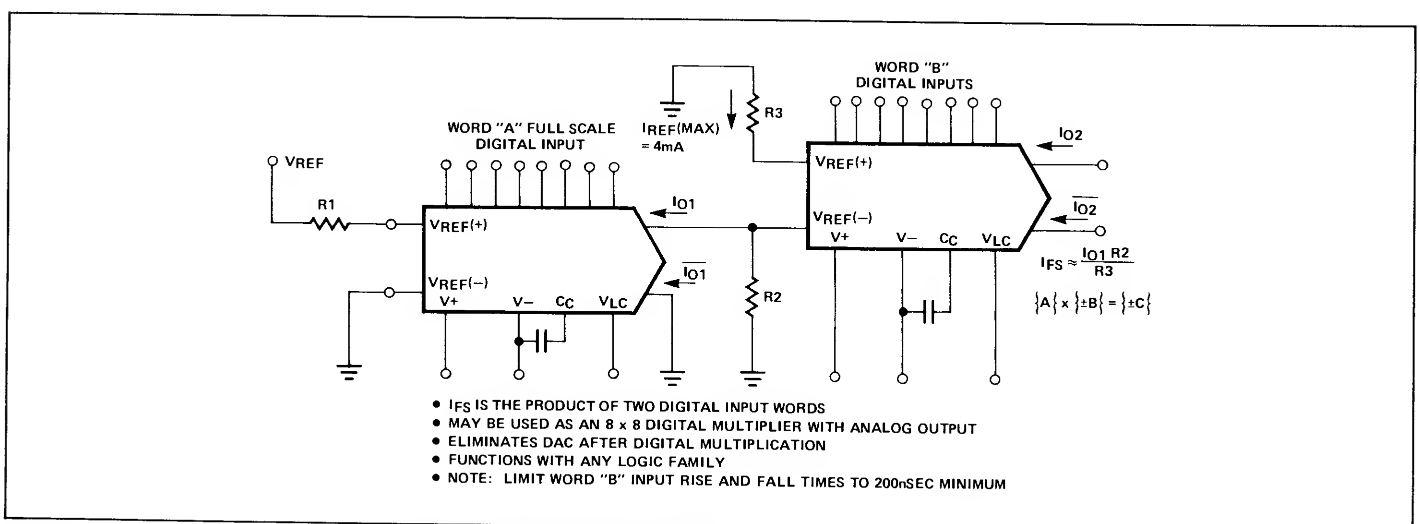


Figure 30. Digitally Controlled Full-Scale Calibration (Multiplier)

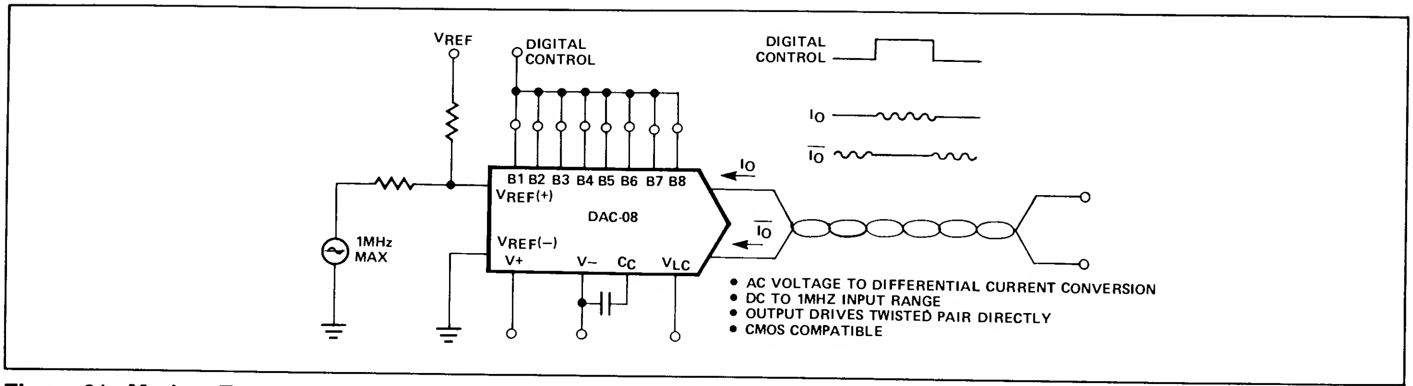


Figure 31. Modem Transmitter

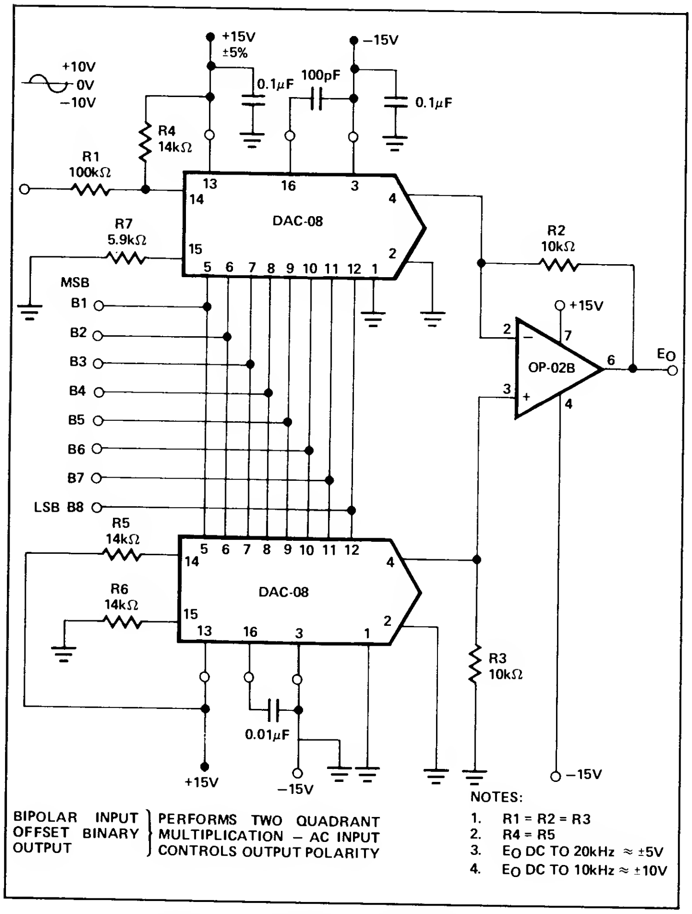


Figure 32. DC-Coupled Digital Attenuator/ Programmable Gain Amplifier

POWER SUPPLIES

POWER SUPPLY REQUIREMENTS

The DAC-08 works with ±4.5V to ±18V supplies allowing use with all standard digital and analog system supply voltages plus most battery voltages. With only 33mW of power dissipation at ±5V and 85ns settling time, it has a lower speed power product than CMOS DACs. Power dissipation is almost constant over temperature, and bypassing is accomplished with 0.01μF capacitors — no large electrolytics are required. These power supply requirements allow:

1. Battery operation.
2. Use of unregulated or poorly regulated power supplies.
3. Use in space-limited areas due to small bypass capacitors.
4. Use in constant power dissipation applications.
5. Common digital and analog power supplies.

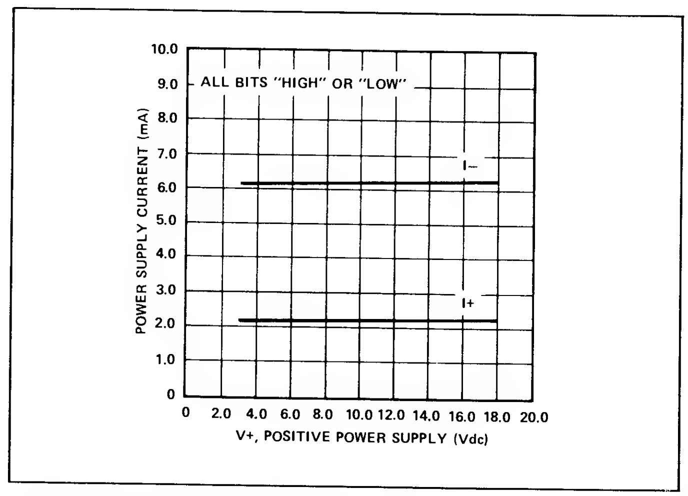


Figure 33. Power Supply Current vs V+

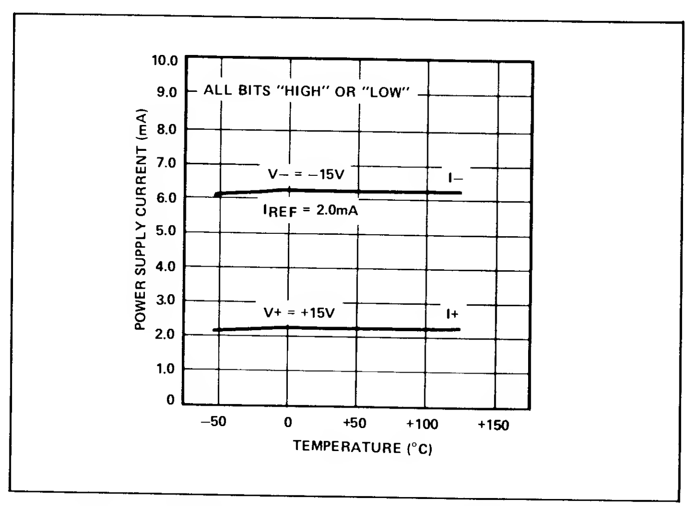


Figure 34. Power Supply Current vs Temperature

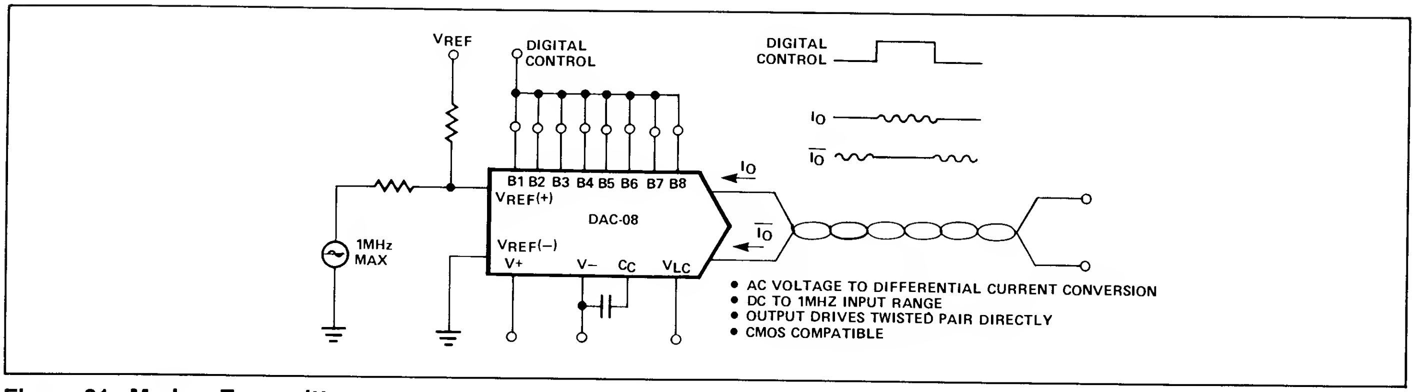
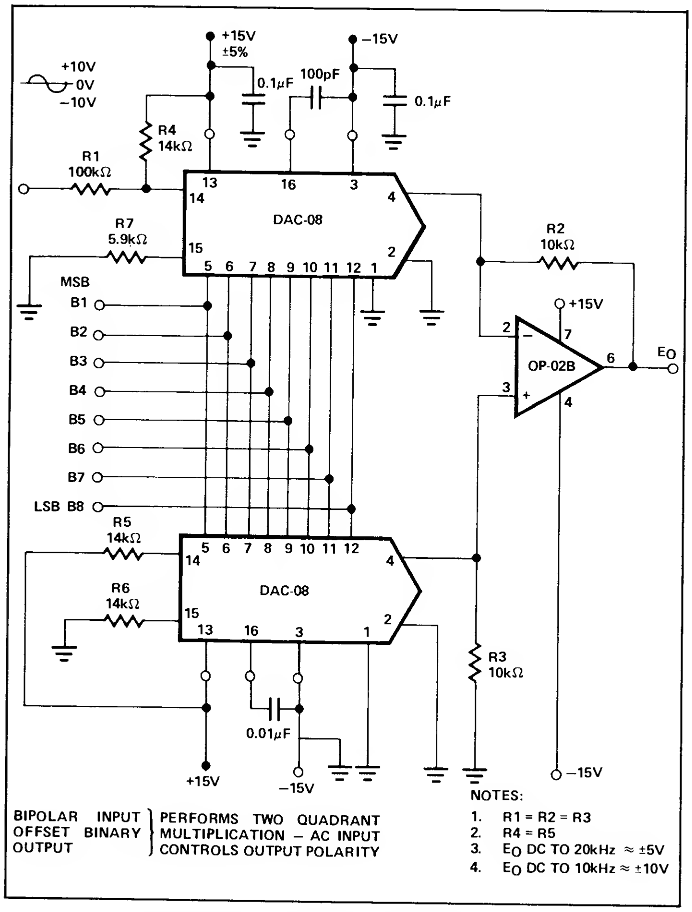


Figure 31. Modem Transmitter



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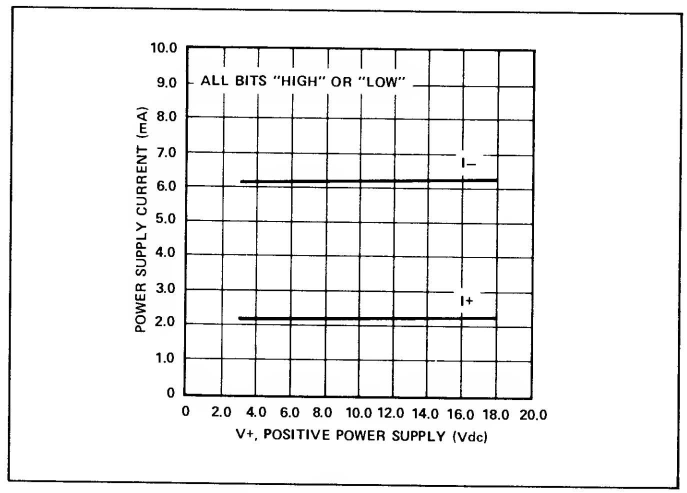

Figure 33. Power Supply Current vs V+

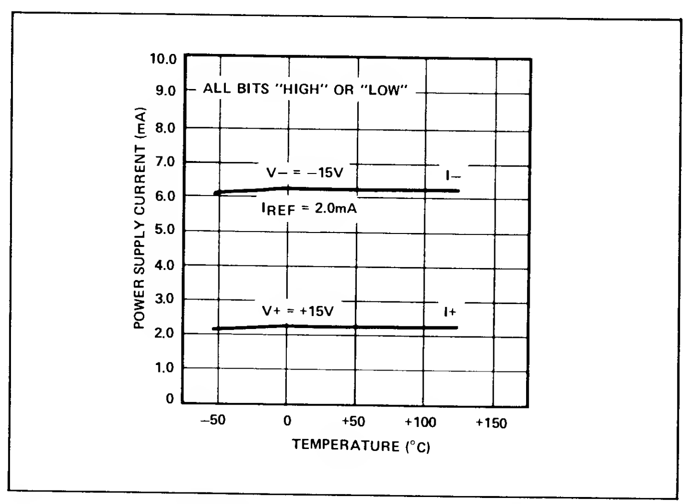

Figure 34. Power Supply Current vs Temperature

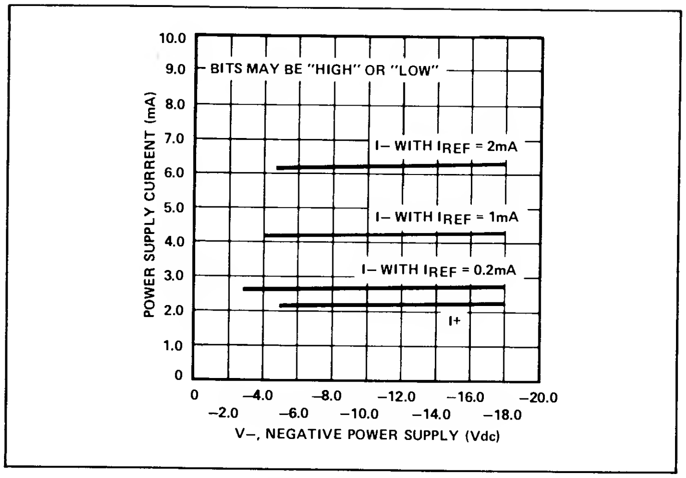

Figure 35. Power Supply Current vs V–

OTHER APPLICATIONS

MICROPROCESSOR APPLICATIONS

The ability to use μP power supply voltages and the ability to interface with any logic family make the DAC-08 especially useful in μP applications:

1. Tracking A/D converters.
2. Successive approximation A/D converters.
3. Direct drive from Hi-Z MOS RAM outputs.

By programming the ROMs with the successive approximation or the tracking A/D algorithm, all of the logic for A/D conversion is contained in the μP. This is a very inexpensive approach, since there is no need for the usual A/D conversion logic packages.

CONCLUSION

High voltage compliance complementary current outputs, universal logic inputs and multiplying capability make the Precision Monolithics DAC-08 the most versatile monolithic high-speed DAC available today.

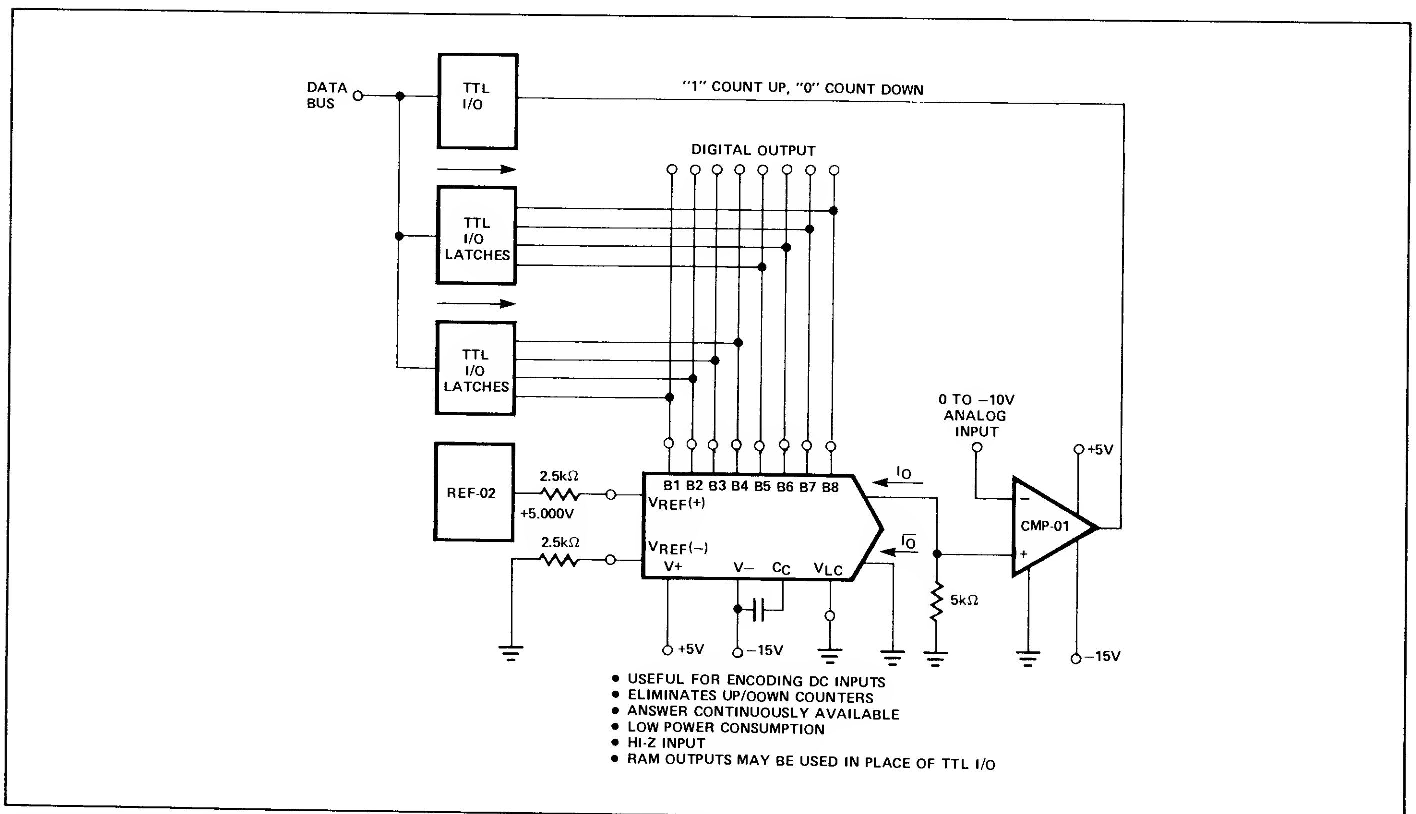

Figure 36. Microprocessor Controlled Tracking A/D Converter